PROBLEM 1 (20 pts)

(a) We discussed the stop-and-wait (reliable) throughput formula in the idealized case when frames do not suffer errors. Consider a link where ACK frames do not suffer errors but data frames are subject to errors and are not received with probability \(0 < p < 1\). For example, \(p = 0.01\) means that, on average, every 100'th frame fails to be successfully received by the receiver. If a frame transmission fails, assume that the retransmission always succeeds. Assume RTT estimation is perfect, i.e., timers never go off prematurely or unnecessarily late. For this slightly more realistic scenario, construct a formula that captures stop-and-wait’s average/expected reliable throughput. Explain how you arrive at the formula.

(b) As an extension of (a), assume that transmission of data frames fail with independent (across successive transmission attempts) probability \(p\). Hence, a data frame may succeed in its first transmission attempt, it may fail in the first attempt but succeed in the second attempt, it may fail in two consecutive attempts but succeed in the third attempt, etc. Construct a formula that captures stop-and-wait’s reliable throughput in the more general case. Explain your reasoning.

PROBLEM 2 (20 pts)

Suppose we aim to support 4 users and their simultaneous bit transmissions using the CDMA-like approach based on linear algebra discussed in class. Find orthogonal 4-D vectors different from the standard unit vectors \((1,0,0,0)\), \((0,1,0,0)\), \((0,0,1,0)\), \((0,0,0,1)\) that will serve as the code vectors of the four users. Assuming a single sender wishes to send 1 bit per receiver—i.e., 4 bits in total—describe what the sender does and what each of the receivers will “hear” (i.e., receive). Explain what each receiver must do to extract (i.e., decode) the bit that was sent to him/her from the vector received. When describing how decoding takes place, highlight where orthogonality comes in handy. What happens to decoding if the code vectors are not orthogonal (although still independent)? How is this related to an issue we encountered when sending bits using amplitude modulation (AM) of electromagnetic waves modeled as complex sinusoids? In the latter, what were the two approaches used to address the problem?

PROBLEM 3 (20 pts)

Find out what carrier frequencies are used by AM radio stations. Based on the bandwidth of each carrier frequency and our understanding of frequencies that the human auditory system is sensitive to, is there an intrinsic limitation to the quality of AM radio broadcast as it is currently architected? Does this help explain the perception that AM radio is adequate for talk radio but less suited for music broadcast? You may ignore that amplitudes degrade/attenuate as EM waves traverse larger distances. As a communication system, how is AM radio different from FDMA multi-user communication discussed in class? Suppose a law mandated that AM radio become digital by transmitting compressed audio data (e.g., mp3). Explain what that would mean and why all AM receivers in car and home stereos would have to be replaced. Does AM radio becoming digital necessarily mean that audio quality increases? Explain your reasoning.